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A METHOD FOR EVALUATING SUNSCREEN PROTECTION FROM LONGWAVE ULTRAVIOLET*

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ABSTRACT

A method for assaying the ability of a sunscreen to protect against longwave ultraviolet radiation is described. Subjects were photosensitized to this radiation by oral administration of demethylchlortetracycline and the efficacy of the sunscreen was tested by subsequent exposure to filtered sunlight. Non-sensitized control subjects were similarly exposed. Interpretation of results observed by direct inspection were compared with those derived by examination of photographs.

Using the model of Maibach *et al.* (1), a method for studying the protective properties of topical sunscreens against radiation of wavelengths greater than 3200 Å was investigated. Two recent observations have made possible the clinical evaluation of this longwave ultraviolet radiation:† 1) Demethylchlortetracycline (DMCT) in sufficient dosage produces photosensitivity to longwave ultraviolet radiation in a majority of individuals (1, 2); and 2) Mylar, an inexpensive, transparent plastic, absorbs all wavelengths below 3100 Å (1, 3, 4). These shorter rays cause ordinary sunburn erythema which, if not absorbed by a suitable filter, may mask the phototoxic reactions of the skin produced by the longer wavelengths in subjects photosensitized with DMCT. These reactions are considered to be phototoxic rather than photoallergic because the majority of subjects become photosensitized when receiving a dosage of DMCT of sufficient magnitude, the reaction presents as an exaggerated sunburn, and no incubation period is necessary.

METHODS AND MATERIALS‡

Twenty healthy Caucasian men 14–30 years of age were chosen for the study. All denied taking medication during the four weeks prior to the study and none was using soaps or artificial sweeteners containing known photosensitizing agents. None gave a history of photosensitivity.

Demethylchlortetracycline (DMCT), 300 mg, and Nystatin U. S. P., 500,000 units, were administered orally, twice daily, beginning at 5:15 P.M. on January 30, 1968, and ending at 8:45 A.M. on February 4, 1968 (ten doses for a total of 3.0 grams of DMCT). A competent observer confirmed each ingestion by each subject. Three control subjects received no medication.

All subjects were exposed to direct sunlight from 10:00 A.M. to 2:00 P.M. on February 4, 1968. All were placed in the prone position with a north-south orientation, their heads directed south. A paper-lined, aluminum foil shield with five round ports, 2¼ inches in diameter, covered the low back and buttocks. Three ports were located across the mid-sacral area and two ports were located on the upper buttocks. The sacral and upper buttock areas were chosen because of the uniformly untanned skin in all subjects. Aluminum foil shielding was used because it was felt that it would best retain its shape when molded to the convexities and concavities presented by the test area. The paper lining consisted of soft, absorbent, disposable paper sheeting which was intended to absorb sweat. A pinhead size spot of gentian violet was used to mark the center of each site and permitted re-centering of the shields in the first two hours before reactions became apparent. All other areas were draped with light weight clothing and paper sheets.

The five test sites were randomized in the twenty subjects and consisted of the following:

Site №1—Control
Site №2—Fresh Mylar (type D - 0.005 inches thick) only
Site №3—Fresh Mylar (type D - 0.005 inches thick) + 1 coat sunscreen§
Site №4—Fresh Mylar (type D - 0.005 inches thick) + 2 coats sunscreen
Site №5—Fresh Mylar (type D - 0.005 inches thick) + sunscreen base

The sunscreen and sunscreen base were applied before exposure by the same individual in a

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† Radiation of wavelength greater than 3200 A.

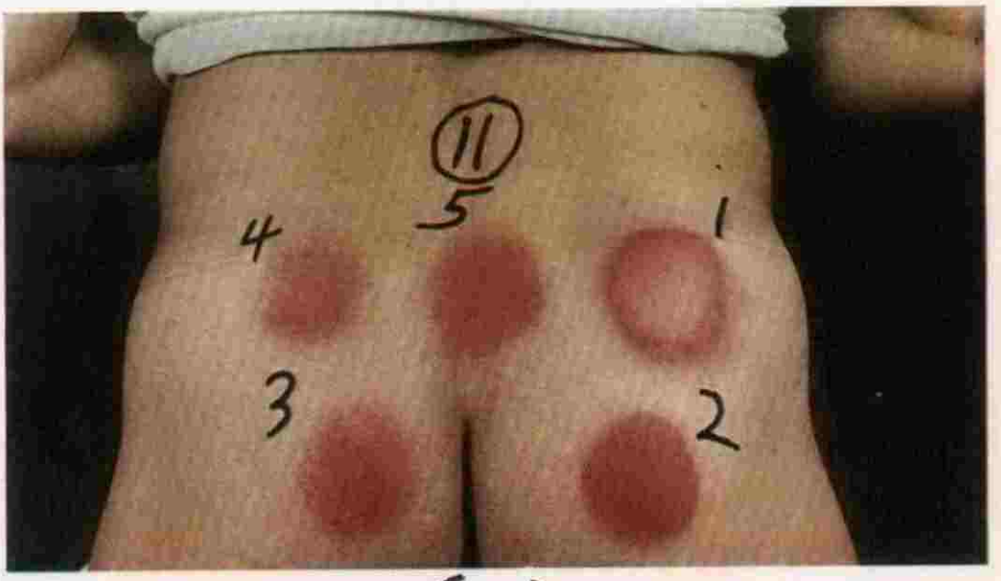
‡ Medical photography by Gordon Schwing, St. Mary's Hospital, Tucson; Serum antibiotic levels by Lederle Laboratories; 10% sulisobenzone supplied as UVAL by Dome Laboratories.

§ 10% sulisobenzone lotion (10% 2 hydroxy-4-methoxy-benzophenone-5-sulfonic acid) was used throughout this study.

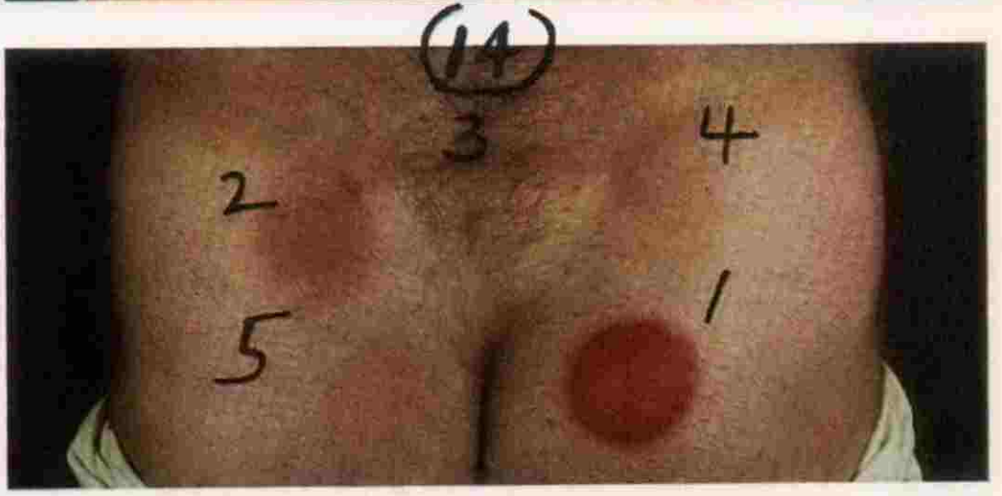
film thickness to approximate normal usage. The sunscreen was reapplied to site #4 at 12:00 noon.

February 4, 1968, in Tucson, Arizona, was a clear, calm day with visibility of 60 miles, humidity of 18% and temperatures from 61° at 10:00 A.M. to 72° at 2:00 P.M. as reported by the United States Weather Station. Declination of the sun was approximately 43° above the horizon which permitted mounting the Mylar filters at an angle. This gave access to the test sites for reapplication of the sunscreen and also ventilation.

Blood specimens were drawn on January 30,



(2)



(1)

FIG. 1. Control subject No. 14 presents an acute sunburn reaction at site #1 (no Mylar filter) produced by erythematogenic ultraviolet rays shorter than 3200 angstroms. No reaction except faint hyperpigmentation is seen at other sites, all of which were protected with Mylar which screened out erythematogenic rays shorter than 3200 angstroms.

FIG. 2. Photosensitized subject No. 11 presents a sunburn reaction plus a phototoxic reaction at site #1 and phototoxic reactions only at all other sites with Mylar which transmitted wavelengths greater than 3200 angstroms. Site #2—untreated. Site #3—1 application of sulisobenzone lotion. Site #4—2 applications of sulisobenzone lotion. Site #5—1 application of lotion base (without sulisobenzone).

1968, prior to the first dose of DMCT, and after completion of the sun exposure. The serum was separated, frozen and shipped for assay of DMCT leve's.

Twenty-seven hours after completion of sun exposure, two dermatologists, uninformed of the code of randomization of the test sites, examined all subjects and recorded their observations. Color photographs of all subjects were then taken with the test sites numbered in accordance with the previously noted code by a professional medical photographer. He used type "L" Ektacolor® balanced for incandescent light. In the printing process type "C" Ektacolor® print paper was used with variation in the color balance established by variation of the filter pack. Those subjects showing marked reactions were reexamined five days after exposure.

RESULTS

Table I presents the readings made by observers at 27 hours. Table II lists the findings derived from comparison of the photographs taken at 27 hours. Table III presents the readings made by observers five days after exposure.

CONCLUSIONS

Conclusions from Table I (Readings by observers at 27 hours). The three control subjects showed 3+ erythema and 1—2+ induration at site №1 (control site). Site №2 (Mylar only) showed 1+ erythema in two control subjects and was negative in the third control subject. All subjects who showed similar reactions at site №2 were considered to be not photosensitized. Conclusions from the results are:

a) Nine of the treated subjects showed 1+ or less erythema at site №2 and were judged not photosensitized. Eight subjects showed 2+ erythema or more at site №2 and were judged to be photosensitized.

b) The sunscreen protected 7 out of 9 non-photosensitized subjects.

c) The sunscreen protected all 8 photosensitized subjects.

d) The sunscreen protected 2 of the 3 controls.

e) In 4 subjects, two coats of sunscreen gave

TABLE I

Readings by observers at 27 hours

Subject no.	Test site number														
	(1)			(2)			(3)			(4)			(5)		
	E	I	P	E	I	P	E	I	P	E	I	P	E	I	P
1	3	2	0	1	0	0	0	0	0	0	0	0	2	1	0
2	3	1	0	1	0	0	1	0	0	0	0	0	2	0	0
3	3	1	0	1	0	0	0	0	0	0	0	0	1	0	0
4	3	3	0	2	1	0	1	0	0	1	0	0	2	1	0
5	3	2	0	1	0	0	1	0	0	1	0	0	0	0	0
6	3	2	0	3	1	0	2	1	0	2	0	0	2	1	0
7	3	3	0	3	1	0	2	0	0	1	0	0	3	1	0
8	3	3	0	2	1	0	1	0	0	1	0	0	2	0	0
9	3	1	0	2	0	0	2	0	0	1	0	0	2	0	0
10	3	1	0	1	0	0	0	0	0	0	0	0	1	0	0
11	3	3	0	3	2	0	1	0	0	1	0	0	3	1	0
12	2	1	0	1	0	0	0	0	0	0	0	0	1	0	0
13	3	1	0	0	0	0	1	0	0	0	0	0	1	0	0
14	3	2	0	1	0	0	0	0	0	0	0	0	1	0	0
15	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0
16	3	1	0	1	0	0	0	0	0	0	0	0	1	0	0
17	3	1	0	1	0	0	0	0	0	0	0	0	0	0	0
18	3	1	0	1	0	0	0	0	0	0	0	0	1	0	0
19	3	1	0	2	0	0	1	0	0	1	0	0	2	0	0
20	3	1	0	2	0	0	1	0	0	1	0	0	2	0	0

E = Erythema I = Induration P = Pigmentation

TABLE II

Comparison of photographs taken at 27 hours

Subject no.	Test site number									
	(1)		(2)		(3)		(4)		(5)	
	E	P	E	P	E	P	E	P	E	P
1	4	0	1	0	0	0	0	0	2	0
2	2	0	1	0	0	0	0	0	1	0
3	3	0	1	0	0	1	0	0	1	1
4	4	0	2	0	1	0	1	0	2	0
5	3	0	1	0	1	0	1	0	0	0
6	3	0	3	0	3	0	1	0	2	0
7	3	0	3	0	2	0	1	0	3	0
8	3	0	2	0	1	0	1	0	2	0
9	3	0	2	0	2	0	1	0	2	0
10	4	0	1	0	0	0	0	0	1	0
11	4	0	4	0	2	0	1	0	2	0
12	2	0	0	0	0	0	0	0	0	1
13	2	0	0	0	0	1	0	0	1	0
14	4	0	0	1	0	1	0	0	0	0
15	3	0	0	1	0	0	0	0	0	0
16	3	0	1	0	0	0	0	0	1	0
17	2	0	0	1	0	0	0	0	0	0
18	3	0	1	0	0	0	0	0	1	0
19	2	0	1	0	0	1	0	1	1	0
20	3	0	2	0	1	0	1	0	2	0

E = Erythema P = Pigmentation

greater protection from erythema than one coat and protected one subject from induration.

f) The sunscreen base gave no protection in 15 subjects (site №5 showing the same reaction as site №2 and greater reactions than sites №3 and №4) and appeared to give some protection in 3 subjects (site №5 less than site №2, and the same as site №3 and №4).

g) Sunscreen protection:

Excellent = 2+ increment between control and both sunscreen sites.
Fair = 1+ increment between control and both sunscreen sites.
Slight = 1+ increment between control and one sunscreen site and equal to the other site.

	Total
Photosensitized subjects:	
Excellent: Subjects 7, 11	(2)
Fair: Subjects 4, 6, 8, 19, 20	(5)
Slight: Subject 9	(1)
Non-photosensitized subjects:	
Excellent: None	(0)
Fair: Subjects 1, 3, 10, 12, 16, 18	(6)
Slight: Subject 2	(1)
None: Subject 5	(1)
Not assessable: Subject 13	(1)
Control Subjects:	
Fair: Subjects 14, 17	(2)
Not assessable: Subject 15	(1)

Conclusions from Table II (*Readings of photographs taken at 27 hours*). The photographs of the control subjects (Nos. 14, 15 & 17) showed only a faint pigmentation in site №2 (probably Mierowsky phenomenon) and no apparent erythema. Therefore, all subjects demonstrating any erythema at site №2 were considered photosensitized. Induration could not be assessed from the photographs and therefore is not noted on the Table. Conclusions from these results are:

a) 15 subjects were considered to be photosensitized. 2 treated subjects were judged not photosensitized.

b) The sunscreen protected 14 photosensitized subjects.

c) In 4 subjects, two coats of sunscreen gave better protection than did one coat.

TABLE III

Readings by observers at 96 hours

Subject no.	Test site number														
	(1)			(2)			(3)			(4)			(5)		
	E	I	P	E	I	P	E	I	P	E	I	P	E	I	P
1	4	1	0	1	0	0	0	0	0	0	0	0	1	0	0
2	Not evaluated														
3	Not evaluated														
4	3	0	1	1	0	0	0	0	0	0	0	0	1	0	0
5	Not evaluated														
6	2	0	1	2	0	0	1	0	0	1	0	0	2	0	1
7	3	0	0	2	0	0	1	0	0	1	0	0	3	0	0
8	3	1	1	2	0	0	1	0	0	1	0	0	2	0	0
9	3	0	1	2	0	0	1	0	0	1	0	0	2	0	0
10	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
11	3	2	2	2	0	0	1	0	0	1	0	0	2	0	0
12	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	Not evaluated														
14	Not evaluated														
15	Not evaluated														
16	Not evaluated														
17	Not evaluated														
18	3	1	1	1	0	0	0	0	0	0	0	0	0	0	1
19	2	0	1	1	0	0	0	0	0	0	0	0	1	0	0
20	3	1	0	1	0	1	0	0	0	0	0	0	1	0	0

E = Erythema I = Induration P = Pigmentation

d) In the 2 non-photosensitized subjects (Nos. 12 and 13) and in all 3 control subjects (Nos. 14, 15, and 17) there was no visible reaction in sites 2, 3, 4, and 5, and therefore protection could not be assessed.

e) The sunscreen base gave no protection in 12 subjects and appeared to give some protection in 3 subjects.

f) Sunscreen protection of photosensitized subjects:

	Total
Excellent: Subjects 7, 11	(2)
Fair: Subjects 1, 2, 3, 4, 6, 8, 10, 16, 18, 19, 20	(11)
Slight: Subject 9	(1)
None: Subject 5	(1)

Conclusions from Table III (Readings by observers at 96 hours). a) Subject ※1 presented marked exfoliation at site ※1. Other subjects showed moderate reduction in the degree of erythema and induration.

b) Most control sites lost much or all of the induration but little or none of the erythema.

c) There was a rather uniform loss of erythema in all Mylar covered sites (Nos. 2, 5).

d) Sunscreen protected sites were consistently 1+ less erythematous than sites ※2 (Mylar only) and ※5 (Sunscreen base).

e) Pigmentation was minimal and occurred predominantly at the periphery of site ※1.

DISCUSSION

The technique described was developed to test under actual conditions the ability of a specific sunscreen to protect a photosensitized individual from a phototoxic reaction to long-wave ultraviolet. Such capability is becoming increasingly desirable since many newer systemic medications (e.g. phenothiazines, thiazides, and tetracyclines) have absorption peaks over 3200 Å. The method should prove adaptable to comparing various sunscreens as well as to establishing the capability of any single agent.

No attempt was made to test the resistance of the sunscreen to removal by sweat, swimming

or other activity. The influence of perspiration in this study would, of course, be less than in climates with greater humidity or in warmer seasons with increased perspiration.

The readings by the observers indicated a mild erythema in 2 of 3 controls whereas the photographs taken at the same time showed only a faint hyperpigmentation. This type of photography must be of professional caliber to be useful, as it was in this study. The unanswered question in this study is whether there were mild, erythematous reactions in the controls which the camera failed to capture or were the eyes of the observers seeing erythema that was not present? An additional problem arises in explaining the erythema (if it was, in fact, erythema) in the control subjects at site #2. It is possible that scattered ultraviolet radiation below 3200 Å bypassed the Mylar filters which were mounted at an angle thus giving a faint primary erythema visible to the observer's eye but not to the camera.

REFERENCES

1. Maibach, J. I., Sams, W. M., Jr. and Epstein, J. H.: Screening for drug toxicity. Arch. Derm., *95:* 12, 1967.
2. Blank, H., Cullen, S. U. and Catalano, P. M.: Photosensitivity studies with demethylchlortetracycline and doxycyline. Arch. Derm., *97:* 1, 1968.
3. Daniels, F., Jr.: Plastic materials for ultraviolet protection. Arch. Derm., *84:* 392, 1961.
4. Sams, W. M., Jr.: The effect of ultraviolet light on a transparent plastic. Arch. Derm., *95:* 225, 1967.